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Nutritional and Soil Compaction Aspects of Establishing Forest Cover on Winter Landings in the Fort St. James Area

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Nutritional and Soil Compaction Aspects of Establishing Forest Cover on Winter Landings in the Fort St. James Area

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EXECUTIVE SUMMARY

In 1979, planting trials to reclaim compacted winter landings (rated as non-productive) were established by the Canadian Forestry Service near Fort St. James. This report provides soil and regeneration performance data to supplement the 5-year assessment of the trials as reported in Arnott *et al.* (1985).

These winter landings were more dense than off-landing areas, particularly at the 10-20 cm and 20-30 cm depths. This increase in soil density appears to be more a function of scalping during landing construction and the exposing of more dense subsoil, than of actual soil compaction by equipment. Additionally, the soil nitrogen, phosphorus, and potassium levels were reduced during landing construction because of the displacement of the forest floor and surface soil. This combination of high soil density and lower soil nutrient status appears to have lowered foliar nitrogen concentration and reduced seedling growth on the landings, compared to that of off-landing natural regeneration.

ACKNOWLEDGEMENTS

In 1979, Reid Collins and Associates Limited, in association with the Canadian Forestry Service, established a trial to reclaim compacted, non-productive forest land near Fort St. James. Seedling performance was measured in 1979 and 1984. The results are presented in File Report PC-48338, *Auger Planting of Lodgepole Pine on Forest Landings, Fort St. James, British Columbia* (1985) by J. T. Arnott, A.Waines, and D. Beddows.

To augment the seedling assessment, Terrasol was contracted to collect relevent soil data and additional seedling data from both the landing and off-landing areas. I wish to thank Jim Arnott for his cooperation and support of this project. The funding provided by the Canadian Forestry Service and the B.C. Ministry of Forests through the FRDA Program is greatly appreciated. I am indebted to the staff at Pacific Soil Analysis Inc. for their assistance with the data collection and laboratory analyses.

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1 INTRODUCTION

Timber harvesting with ground-based equipment necessitates the construction of skid roads and landings which may alter the soil's chemical and physical characteristics and adversely affect site productivity (Froehlich 1973). The result is a complex interaction between soil texture, changes in soil properties, and tree species (Greacan and Sands 1980). The possible causes of reduced tree growth on landing areas are:

1. increased resistance to root penetration due to higher soil density (Pomeroy 1949; van der Weert 1974; Haines *et al.* 1975; Heilman 1981; Halverson and Zisa 1982; Hildebrandt 1983);
2. poor soil aeration resulting from a loss of soil pore structure (Wiersum 1957; Cannell 1977; Hildebrandt and Wiebel 1982; Gent *et al.* 1983);
3. limited nutrient availability following displacement of the forest floor and top soil, in combination with causes (1) and (2) (Herring and McMinn 1980; Castillo *et al.* 1982);
4. restricted activity of soil micro- and macro-organisms (Skinner and Bowen 1974; Mitchell *et al.* 1982).

Estimates of tree volume reduction on compacted skid roads range from 45% after 26 years (Perry 1964) to 80% after 32 years (Wert and Thomas 1981; Jakobsen 1983). The volume loss on more heavily compacted landings, particularly summer landings, can be expected to be even greater, up to a possible total loss of commercial production (Carr 1985). The losses associated with skid roads and landings, when prorated over an entire cutblock, could amount to at least 12% of the commercial forest production (Wert and Thomas 1981).

2 OBJECTIVE

The primary objective of this project was to measure selected soil physical and chemical parameters on landings and adjacent cutover areas in the Fort St. James areas to ascertain the relative effects of winter landing construction on soil properties, and the resulting effect on tree growth. Additionally, foliar nutrient status of the established plantations on landings and natural regeneration on off-landing areas was measured. Seedling height-growth data from the off-landing areas were collected to supplement the height data from the landing seedlings as reported in Arnott *et al.* (1985).

3 MATERIALS AND METHODS

3.1 Study Area

The study area was located north of Fort St. James, B.C., near Tezzeron Lake (54°39'N, 124°23'W). Situated on the Nechako Plain of the Interior Plateau (Holland 1964), the area features an Orthic Gray Luvisol soil that has developed over a compact, basal till deposit (Cotic *et al.* 1974). As part of the Sub-Boreal Spruce (SBS) biogeoclimatic zone (Krajina 1965), stands of the k3-01 ecosystem unit (in which this study was located) are composed of lodgepole pine (*Pinus contorta* Dougl.) in association with white spruce (*Picea glauca* (Moench) Voss) and Douglas-fir (*Pseudotsuga menziesii* var. *glauca* (Biessn.) Franco) (DeLong *et al.* 1984).

The landings on which the experiment was located were part of winter logging operations with rubber-tired skidders in 1976 and 1977. The surface organic and mineral soil horizons on the landings were removed by blade scarification, exposing bare mineral soil. Winter operations are thought to be unlikely to compact surrounding soils significantly.

3.2 Sampling Procedures

Twenty of the original 25 landings were selected for comparative bulk density analysis between the landing and off-landing areas. Eight of the landings were randomly selected for comparison of soil nutrient

pools (N, P, and K) and tree foliar nutrient content (N, P, and K). Additionally, seedling height growth of naturally regenerated lodgepole pine in the off-landing areas was also recorded.

Each landing was divided into four subsampling compartments corresponding to previously established planting stock trials (Arnott *et al.* 1985). The observation point in each of the landing compartments was randomly located. The corresponding off-landing subsampling points (four per landing) were located approximately 30 m from the outer edge of the landing within an area defined by projecting the landing subsampling compartment boundaries.

3.3 Soil Bulk Density

Soil density was measured using a single probe nuclear densitometer (Campbell Pacific MC-1), with probe depths of 10, 20, and 30 cm. Standard procedures were used for wet density, moisture content, and dry density calculations. The dry density of individual layers (0-10 cm, 10-20 cm, and 20-30 cm) was determined algebraically.

3.4 Soil Chemical Data

Soil nutrient pools for N, P, and K were assessed in samples from the eight randomly selected landings. Subsampling locations corresponded to those used for soil density determination. For the plots within the landing, a soil core approximately 5 cm in diameter was taken to a depth of 20 cm. In the off-landing plots, a 78.5-cm^2 section of the forest floor was collected and the soil core then taken in the mineral soil. All samples were transported to Pacific Soil Analysis Inc., Vancouver, B.C. Sample preparation and the following analysis were performed based on the *Methods Manual: Pedology Laboratory* (Lavkulich 1980):

- total soil N: using a semi-micro Kjeldahl digest, with colorimetric determination done using a Technicon autoanalyzer
- available soil P: using the Bray P-1 method
- available soil K: using a Morgan's extraction (1.0 N NaOAc) in conjunction with atomic absorption
- forest floor N, P, and K: using a Caro's acid digest, with N and P colormetrically determined on a Technicon autoanalyzer, and K measured by atomic absorption

Off-landing nutrient pools are the sum of measured soil nutrient content and forest floor content. (For example, P pool = available P in mineral soil + total organic forest floor P.) Analysis of variance was used for comparison of on- and off-landing nutrient pools.

3.5 Foliar Nutrient Content and Off-Landing Tree Growth

At each of the subsampling locations (both on- and off-landing) associated with the eight primary landings, a 50-m^2 circular regeneration plot (radius 3.99 m) was established. Samples of the current-year's foliage were collected from the upper third of the three dominant pines to form a composite foliar sample for the subplot. Foliar samples were analyzed for N, P, and K concentrations using a Caro's acid digest, with N and P determined colorimetrically on a Technicon autoanalyzer and K measured by atomic absorption (Ballard and Carter 1986). Additionally, the "100-needle dry weight" of each composite sample was determined. Analysis of variance was performed on the data.

In the off-landing regeneration plots, the total height, internodal length, and age of the three dominant pines were measured. Height over age curves were plotted to compare relative growth of the natural regeneration on the off-landing area with results from Arnott *et al.* (1985) for planted trees on the landings. This analysis was performed by the Canadian Forestry Service using analysis of variance.

4 RESULTS AND DISCUSSION

4.1 Soil Bulk Density

The soil density data presented in Table 1 are similar to density levels measured on other winter landings in the Fort St. James area (Carr 1985). Soil bulk densities at all three depths are significantly greater on the landings. The off-landing density in the 10- to 20-cm and 20- to 30-cm layers corresponds well to the density observed in the 0- to 10-cm and 10- to 20-cm layers on the landing. It would appear that increased soil densities due to winter landing construction are more the result of exposing denser subsoil material by scalping, rather than of actual soil compaction by logging equipment. During winter harvesting operations, snow cover or frozen soil conditions would reduce the compactive forces from logging equipment operation.

TABLE 1. Soil bulk density (kg/m^3) comparison between landing and off-landing areas

Depth (cm)	Off-landing	Landing
0-10	1080 (160)[1] a	1345 (140) b[2]
10-20	1390 (150) a	1690 (225) b
20-30	1560 (180) a	1735 (140) b

[1] Parentheses contain standard deviations based on 20 observations.
[2] Within each row, means followed by different letters are significantly different ($p \leq 0.05$).

4.2 Soil Nutrient Levels

The soil nutrient pool comparison illustrates the adverse effect of scalping the forest floor and surface soil during landing construction (Table 2). The levels of N, P, and K are all significantly ($p \leq 0.05$) reduced. This reduction would have been even greater except for the higher density of the landing soil (approximately 20%) compared to that in off-landing areas. The P pool, which is closely associated with soil organic matter, was substantially affected by landing construction. Approximately 90% of the P pool has been removed by scalping of the forest floor (41.1 t/ha) and top soil. The residual available P concentration on the landing (5.4 ppm) was significantly lower than on the surrounding areas (32.6 ppm), and is far below the recommended level for commercial production of *Pinus banksiana* Lamb. (Monenco Consultants Ltd. 1983).

TABLE 2. Nutrient comparison (kg/ha), to a depth of 20 cm, between off-landing and landing areas

	Off-landing			Landing
	Forest floor	Soil	Total	Total
N	529 (98)	1782 (442)[1]	2311 (480) a[2]	1760 (380) b
P	70 (9)	63 (50)	133 (50) a	13 (7) b
K	84 (14)	158 (45)	242 (43) a	174 (52) b

[1] Parentheses contain standard deviations of eight replications.
[2] Within each row, mean totals followed by different letters are significantly different ($p \leq 0.05$).

The soil N and K levels appear to be more affected by the removal of the forest floor than by the loss of surface soil. In both cases, the loss of the forest floor can account for the difference (24% and 28% for

N and K, respectively) between off-landing and landing nutrient levels. Although the total soil N concentration was significantly lower ($p \leq 0.05$) on the landing area (0.074%) than on the off-landing area (0.096%), the increase in soil density offset this difference. The available soil K concentration did not differ significantly between landing and off-landing soils (84 vs. 73 ppm).

4.3 Foliar Nutrient Concentration

The foliar nutrient data presented in Table 3 indicate a significantly lower ($p \leq 0.05$) N concentration in the trees planted on the landings compared to the off-landing natural regeneration. Although not evident in the needle weight data, this difference was visually apparent in the respective needle colours. The foliar N concentration of trees on the landing is at a level indicating severe deficiency for lodgepole pine, while foliar concentrations of P and K are adequate (Weetman *et al.* 1985; Ballard and Carter 1986). This nutrient deficiency would be expected to increase with time as the tree roots, growing in a soil of restrictive density, further deplete accessible soil N. Additional reductions of other foliar nutrient levels, particularly P, may be expected because of low available nutrient pools in the residual landing soil.

TABLE 3. Foliar nutrient concentration (% dry mass) and 100-needle weight (g) for landing and off-landing areas

Nutrient	Off-landing		Landing	
N	1.29	(0.07) [1] a	1.19	(0.10) b [2]
P	0.161	(0.010) a	0.154	(0.014) a
K	0.596	(0.055) a	0.0556	(0.071) a
100-needle	1.28	(0.14) a	1.26	(0.16) a

[1] Parentheses contain the standard deviations of eight replications.

[2] Within each row, means followed by the same letter are not significantly different ($p \leq 0.05$).

4.4 Tree Height

Height growth of planted trees on the landing (bareroot stock) and of natural regeneration on the surrounding cutover is shown in Figure 1. By the time the trees were 3 years old, the height of the naturally regenerated lodgepole pine in the off-landing areas was significantly greater than that of the trees planted on the landing. That difference has increased in each subsequent year.

5 SUMMARY

Surface soil horizons were removed when landings were constructed, exposing denser subsoil and reducing the soil nutrient pool. Foliar N of the trees on the landings in this study is at a level indicating a severe deficiency (Weetman *et al.* 1985; Ballard and Carter 1986).

Although trees were successfully established on these winter landings, their growth is much poorer than that of the natural regeneration in the surrounding cutover area. High soil density and reduced soil nutrient pools appear to have combined to make commercial forest production on landing areas very doubtful within the current rotation. The implication from the results of this study is that some form of site rehabilitation (such as soil tillage, fertilization, and/or spreading of topsoil) must be considered if the landing areas are to be capable of sustaining adequate growth of planted lodgepole pine seedlings within an acceptable time frame.

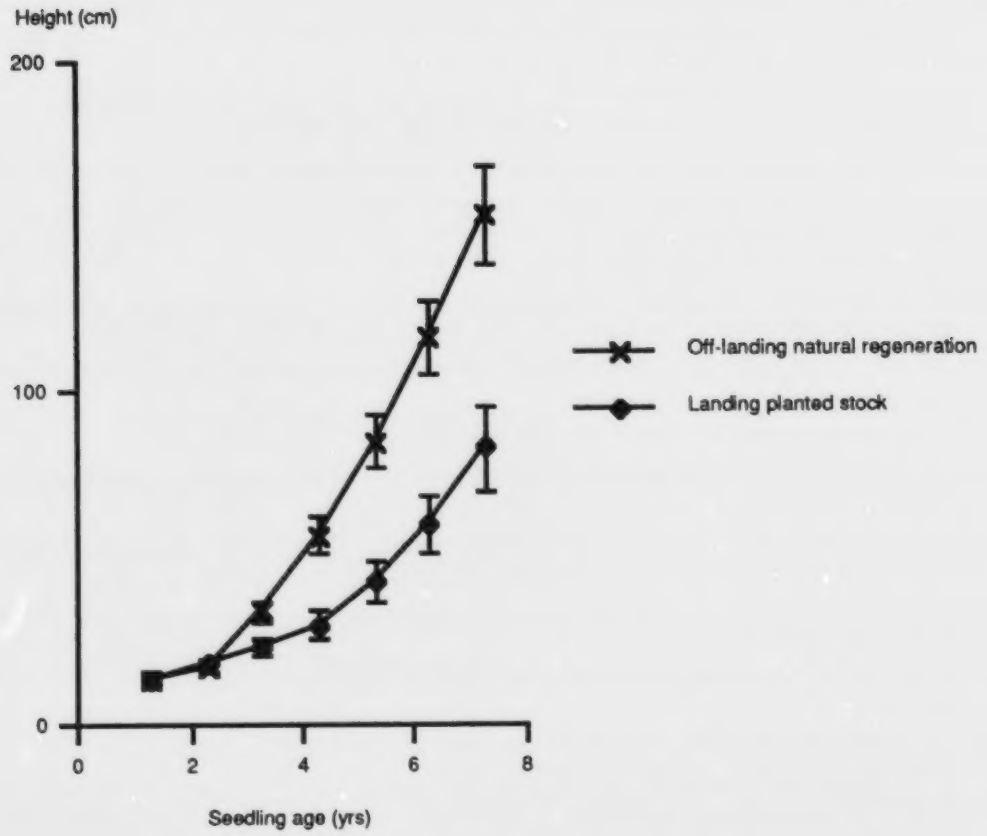

FIGURE 1. Age versus height curves for juvenile growth of landing and off-landing lodgepole pine. Error bars indicate range of standard deviation.

6 LITERATURE CITED

Arnott, J.T., A. Waines, and D. Beddows. 1985. Auger planting of lodgepole pine on forest landings, Fort St. James, British Columbia. Can. For. Serv. File Report PC-48-338. Can. For. Serv. Pac. For. Res. Cent., Victoria, B.C.

Ballard, T.M., and R.E. Carter, 1986. Evaluating forest stand nutrient status. B.C. Min. For. Land Manage. Rep. No. 20.

Cannell, R.Q. 1977. Soil aeration in relation to root growth and soil management. Appl. Bio. 1977(2): 1-86.

Carr, W.W. 1985. Restoring productivity on severely degraded forest soil in British Columbia. Ph.D thesis. Univ. of B.C., Faculty of Forestry, Vancouver, B.C.

Castillo, S.R., R.H. Dowdy, J.M. Bradford, and W.E. Larson. 1982. Effects of applied mechanical stress on plant growth and nutrient uptake. Agron. J. 74: 256-257.

Cotic, I, J. van Barneveld, and P.N. Sprout. 1974. Soils of the Nechako-Francois lake area. B.C. Dep. Agric., Soil Br., Victoria, B.C.

DeLong, C., G. Hope, and A. McLeod. 1984. A field guide for the identification and interpretation of the ecosystems of the SBSk3 in the Prince George Forest Region, First approx. B.C. Min. For., Ecology Section, Prince George For. Region.

Froehlich, H.A. 1973. The impact of even-age forest management on physical properties of soils. *In* Proc. Symp. on Even-Age Management, R. Herman and D. Lavender (editors). Oreg. State Univ., Corvallis, Oreg., pp. 199-219.

Gent, J.A., R. Ballard, and A.E. Hassan. 1983. The impact of harvesting and site preparation on physical properties of Lower Coastal Plain soils. Soil Sci. Am. J. 47: 595-598.

Grecan, E.L., and R. Sands. 1980. Compaction of forest soils - a review. Aust. J. Soil Res. 18: 163-189.

Haines, L.W., T.E. Maki, and W.G. Sanderford. 1975. The effects of mechanical site preparation treatments on soil, productivity, and tree growth. *In* Forest soils and forest land management. Univ. of Laval Press, Quebec City, Que., pp. 379-395.

Halverson, H.G. and R.P. Zisa. 1982. Measuring the response of conifer seedlings to soil compaction stress. U.S. Dept. Agric. For. Serv., N.E. For. Range Exp. Stn. Res. Pap. NE-509.

Heilman, P. 1981. Root penetration of Douglas fir seedlings into compacted soils. For. Sci. 47: 660-666.

Herring, J.J. and R. G. McMinn. 1980. Natural and advanced regeneration of Engelmann spruce and subalpine fir compared 21 years after site treatment. For. Chron. 56(2): 55-57.

Hildebrandt, E.E. 1983. (The influence of soil compaction on soil dunctions on forest sites.) Forstwiss. Centralbl. 102(2): 111-125.

Hildebrandt, E.E. and M. Wiebel. 1982. (The influence of vehicle movement on site quality as represented by soil physical measurements.) Allg. Forst - jagdztg. 153 (1/2): 24-34.

Holland, S.S. 1964. Land forms of British Columbia: a physiographic outline. B.C. Dep. of Mines Pet. Resources. Victoria, B.C. Bull. No. 48.

Jakobsen, B.F. 1983. Persistence of soil compaction effects in a Forest Kraznozem. Aust. For. Res. 13: 305-308.

Krajina, V.J. 1965. Biogeoclimatic zones and biogeocoenoces of British Columbia. Ecol. West. N. Am. 1: 1-17.

Lavkulick, L. 1980. Methods manual Pedology Laboratory., Univ. B. C., Dep. Soil Science, Vancouver, B.C..

Mitchell, M.L., A.E. Hassan, C.B. Davey, and J.D. Gregory. 1982. Loblolly pine growth in compacted greenhouse soils. Trans. ASEA (1982): 304-307 and 312.

Moneco Consultants Ltd. 1983. Soil reconstruction design for the reclamation of oilsands tailings. Al. Land Conserv. and Reclam. Council, Edmonton, Alta. Rep. SES 6-RRTAC No. 83-1.

Perry, T.O. 1964. Soil compaction and loblolly pine growth. U.S. Dep. Agric. For. Serv., Tree Planters' Notes No. 67:9.

Pomeroy, K.B. 1949. The germination and initial establishment of loblolly pine under various surface soil conditions. J. For. 47: 541-543.

Skinner, M.F. and G.D. Bowen. 1974. The penetration of soil by mycelial strands of ectomycorrhizal fungi. Soil Bio. Biochem. 6: 56-61.

Van der Weert, R. 1974. Influence of mechanical forest clearing on soil conditions and the resulting effects on root growth. Trop. Agric. 51(2): 325-331.

Weetman, G.F., R.C. Yang and I.E. Bella. 1985. Nutrition and fertilization of lodgepole pine. *In* Proc. Symp. on Lodgepole Pine: The Species and its Management. D.M. Baumgartner, R.G. Krebill, J.T. Arnott, and G.F. Weetman (editors). Cooperative Extension, Wash. State Univ., Pullman, Wash., pp. 225-232.

Wert, S. and B.R. Thomas. 1981. Effects of skid roads on diameter, height and volume in Douglas fir. Soil Sci. Soc. Amer. J. 45: 619-632.

Wiersum, L.K. 1957. The relationship of the size and structural rigidity of pores to their penetration by roots. Plant and Soil 9: 75-85.